Trigger Rates

Tony Frawley
Florida State University

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Introduction

I would like to touch on **triggering issues** for RHIC I (~ 2008) and for RHIC II.

But first, I will review some **luminosity and rate** estimates that we will need. I assume that we will have the VTX detector in place, so will use a 10 cm Z vertex cut.

RHIC I (~ 2008)

CAD has recently put out some luminosity guidelines in which the p-p luminosity decay rate in stores has been revised for RHIC I ~2008. These are in “RHIC Collider Projections (FY2005-FY2008)”, by T. Roser, W. Fischer, M. Bai and F. Pilat.

Species	**Peak Lum.**	**Average Lum.**	**Average/peak**
p-p	89×10^{30}	72×10^{30}	**0.81**
Au-Au	36×10^{26}	9×10^{26}	0.25

What is new here is that the p-p luminosity decay rate is projected to be very small, resulting in a **larger integrated luminosity sampled**.

RHIC I luminosity (~ 2008)

Assumptions:

5+14 week run
Max. DAQ throughput **6 KHz** by ~ 2008
RHIC Z vertex σ = **20 cm**, 80% in central peak
Maximum archiving rate **1200 MB/s** (before compression)
σ_{BBC}(p-p) = 21.8 mb (at 200 and 500 GeV), σ_{mVTX}(p-p) = 42 mb (at 200 and 500 GeV)

Species	Peak RHIC luminosity	Trigger	Z-cut (cm)	Peak MB rate	------Integrated luminosity--------- Total	DAQ	minbias archived
Au-Au	32 x 10^{26}	BBC	10	6.2 KHz	0.76 nb^{-1}	0.76 nb^{-1}	0.73 nb^{-1}
p-p(200)	0.89 x 10^{32}	BBC	10	0.6 MHz	67.2 pb^{-1}	0.84 pb^{-1}	0.42 pb^{-1}
p-p(500)	1.5 x 10^{32}	BBC	10	1.0 MHz	113 pb^{-1}	0.84 pb^{-1}	0.42 pb^{-1}
p-p(200)	0.89 x 10^{32}	**mVTX**	10	1.15 MHz	67.2 pb^{-1}	0.44 pb^{-1}	0.22 pb^{-1}
p-p(500)	1.5 x 10^{32}	**mVTX**	10	1.9 MHz	113 pb^{-1}	0.44 pb^{-1}	0.22 pb^{-1}

RHIC II

RHIC II luminosity guidelines are in "RHIC II Machine Plans" presented by Thomas Roser at the RHIC Open Planning Meeting in December, 2003.

Species	Peak Lum.	Average Lum.	Average/peak
p-p (200)	3×10^{32}	2.7×10^{32}	0.9
p-p (500)	5×10^{32}	4.5×10^{32}	0.9
Au-Au	90×10^{26}	70×10^{26}	0.78

RHIC II luminosity (FEMS not demultiplexed)

Assumptions:

5+14 week run
Max. DAQ throughput **8 KHz** by RHIC II
RHIC Z vertex σ = **10 cm**, 80% in central peak
Maximum archiving rate **2400 MB/s** (before compression)
σ_{BBC}(p-p) = 21.8 mb (at 200 and 500 GeV), σ_{mVTX}(p-p) = 42 mb (at 200 and 500 GeV)

Species	Peak RHIC luminosity	Trigger	Z-cut (cm)	Peak MB rate	------Integrated luminosity---------- Total	DAQ	minbias archived
Au-Au	90 x 10^{26}	BBC	10	31 KHz	13.6 nb^{-1}	3.84 nb^{-1}	1.92 nb^{-1}
p-p(200)	3.0 x 10^{32}	BBC	10	3.6 MHz	453 pb^{-1}	1.12 pb^{-1}	0.56 pb^{-1}
p-p(500)	5.0 x 10^{32}	BBC	10	6.0 MHz	756 pb^{-1}	1.12 pb^{-1}	0.56 pb^{-1}
p-p(200)	3.0 x 10^{32}	**mVTX**	10	6.9 MHz	453 pb^{-1}	0.58 pb^{-1}	0.29 pb^{-1}
p-p(500)	5.0 x 10^{32}	**mVTX**	10	11.5 MHz	756 pb^{-1}	0.58 pb^{-1}	0.29 pb^{-1}

RHIC II luminosity (FEMS are demultiplexed)

Assumptions:

5+14 week run
Max. DAQ throughput **16 KHz** by RHIC II
RHIC Z vertex σ = **10 cm**, 80% in central peak
Maximum archiving rate **3600 MB/s** (before compression)
σ_{BBC}(p-p) = 21.8 mb (at 200 and 500 GeV), σ_{mVTX}(p-p) = 42 mb (at 200 and 500 GeV)

Species	Peak RHIC luminosity	Trigger	Z-cut (cm)	Peak MB rate	------Integrated luminosity---------- Total	DAQ	minbias archived
Au-Au	90 x 10^{26}	BBC	10	31 KHz	13.6 nb^{-1}	7.68 nb^{-1}	3.45 nb^{-1}
p-p(200)	3.0 x 10^{32}	BBC	10	3.6 MHz	453 pb^{-1}	2.24 pb^{-1}	1.12 pb^{-1}
p-p(500)	5.0 x 10^{32}	BBC	10	6.0 MHz	756 pb^{-1}	2.24 pb^{-1}	1.12 pb^{-1}
p-p(200)	3.0 x 10^{32}	**mVTX**	10	6.9 MHz	453 pb^{-1}	1.16 pb^{-1}	0.58 pb^{-1}
p-p(500)	5.0 x 10^{32}	**mVTX**	10	11.5 MHz	756 pb^{-1}	1.16 pb^{-1}	0.58 pb^{-1}

Quarkonium available yields at 200 GeV

species	trigger	Z-cut	luminosity	$J/\psi \rightarrow ee$	$J/\psi \rightarrow \mu\mu$	$\psi' \rightarrow \mu\mu$	$\Upsilon \rightarrow ee$	$\Upsilon \rightarrow \mu\mu$
			RHIC I					
Au-Au	BBC	10	0.76 nb^{-1}	2600	20100	740	16	43
p-p	BBC	10	67.2 pb^{-1}	9800	77600	2850	60	165
p-p	**mVTX**	10	67.2 pb^{-11}	13600	107000	3960	86	228
			RHIC II					
Au-Au	BBC	10	7.6 nb^{-1}	26000	201000	7430	160	430
p-p	BBC	10	453 pb^{-1}	67000	520000	19200	416	1100
p-p	**mVTX**	10	453 pb^{-1}	93000	723000	26700	570	1520

(from http://www.phenix.bnl.gov/p/draft/frawley/planning/heavy_light_yields.xls)

Assumes that BBC trigger efficiency is 0.75 for J/ψ, ψ' and Υ production into PHENIX, while mVTX trigger efficiency is 1.0.

Open charm and beauty (muon arms) in 200 GeV pp

Era	Trigger	Zcut	Lum	D→μX		B→μX		B→J/y→μμ	
			avail	samp.	minb.	samp.	minb.	samp.	minb.
RHIC I	BBC	10	67.2 pb^{-1}	3.2 10^{8}	2.0 10^{6}	7.9 10^{5}	4.9 10^{3}	1900	12
	mVTX	10	67.2 pb^{-1}	4.4 10^{8}	1.4 10^{6}	1.1 10^{6}	3.6 10^{3}	2500	8
RHIC II	BBC	10	453 pb^{-1}	2.1 10^{9}	2.7 10^{6}	5.3 10^{6}	6.6 10^{3}	12900	16
	mVTX	10	453 pb^{-1}	2.9 10^{9}	1.9 10^{6}	7.0 10^{7}	4.6 10^{3}	17200	11

Rates are from Pat McGaughey. numbers under “samp” are yields in the available luminosity. Numbers under “minb” are yields in the archived minbias sample.

Assumes that BBC trigger efficiency is 0.75 for D, B production, while mVTX trigger efficiency is 1.0.

For **B→J/y→μμ** a 1 mm vertex cut retains 39% of decays.

Overall trigger requirements

Era	Species	Trigger	Luminosity available	% archived as minbias	Peak rate KHz	archived rate KHz	Trigger rejection (2* peak / archived)
RHIC I	Au-Au	BBC	0.76 nb^{-1}	96	6.2	5.8	-
	p-p(500)	BBC	113 pb^{-1}	0.37	1000	6.0	330
	p-p(500)	mVTX	113 pb^{-1}	0.19	1900	6.0	630
RHIC II	Au-Au	BBC	13.6 nb^{-1}	14.1	31	8.0	8
	p-p(500)	BBC	756 pb^{-1}	0.07	6000	8.0	1500
	p-p(500)	mVTX	756 pb^{-1}	0.04	11500	8.0	2880
RHIC II	Au-Au	BBC	13.6 nb^{-1}	25	31	16.0	4
(demuxed)	p-p(500)	BBC	756 pb^{-1}	0.15	6000	16.0	750
	p-p(500)	mVTX	756 pb^{-1}	0.08	11500	16.0	1440

For all cases except RHIC I AuAu, assume we use **50% of the bandwidth** to archive minbias data. The trigger rejection is the **overall** trigger rejection needed to fit **all rare event triggers combined** into the remaining 50% of the bandwidth.

Any individual trigger will need ~ 5-10 times the overall trigger rejection

Individual Triggers

Assume we use triggers:

- Single e
- Single μ in south
- Single μ in north
- Dielectron
- Dimuon in south
- Dimuon in north
- High p_T γ in EMC

and **later**:

- High energy γ in NCC
- Forward muon upgrade trigger

So **on average** each trigger will need ~ 1/7 of the overall trigger rejection.

What triggers will we have?

MUIDLL1 (see John Lajoie's talk at this meeting):

Trigger	p-p rej. (3/5)	Au-Au rej. (3/5)	Au-Au rej. (4/5)	Au-Au rej. (4/5, strip rej.)
South 1D	584	2.8	5.1	16.4
South 1D1S	28,700	3.1	5.3	18.5
South 2D	200,903	4.7	15.3	162

Forward Muon Upgrade (see Forward Upgrade LOI)

Still in proposal stage, expect rejection of **2,000 to > 20,000** for single muons in p-p, **depending on the momentum cut**. Primarily for W decays in p-p, but probably useful for c, $b \rightarrow \mu$ at very high p_T.

Nose Cone Calorimeter high energy trigger (right?)

What do we need maximum luminosity for?

- Bottomonium
- J/ψ (higher p_T)
- Excited Charmonium (γ-J/ψ)
- γ-jet physics
- c, b$\rightarrow$ μ (higher p_T)
- W physics
- Charm correlations
- Hadrons in muon arms

Where do we have a problem?

Prescale shown is: **(needed rejection / available rejection from MuIDLL1)**.
FMU = Forward Muon Upgrade trigger, NCC = Nose Cone Calorimeter trigger. Assume BBC as minbias trigger.

Topic	**--- p-p (500)---**		**---- Au-Au -----**	
	2008	**RHICII**	**2008**	**RHICII**
Bottomonium	1D1S	1D1S	MB	2D
J/ψ (higher p_T)	1D1S	1D1S	MB	2D
Excited Charmonium (γ-J/ψ)	-	1D1S	-	2D
γ-jet physics	-	(NCC)	MB	(NCC)
c, b$\rightarrow$ μ (higher p_T)	**1D/4**	**1D/20**	MB	**1D/3**
W physics	-	(FMU)	-	-
Charm correlations	**1D/4**	**1D/20**	MB	**1D/3**
Hadrons in muon arms	1D/4	1D/20	MB	MB

Note that 2D trigger for A-uAu needs 4/5 gaps, strip rejection - efficiency poor?

Summary

Things don't look so bad!

We have to assume that the forward muon trigger upgrade will appear in time for W physics at RHIC II, and that the Nose Cone Calorimeter trigger will have a suitable high energy trigger.

Single muons from MUIDLL1 will have to be prescaled at highest luminosities. Problem for **beauty**, and for **charm correlations**.

- The forward muon trigger upgrade will help for high p_T muons, although details are still fuzzy. Is that enough?
- Can the VTX detector be used to increase single muon rejection?

A good minbias trigger for p-p would be nice - possibly the VTX. This is being looked at.

Hadron R_{cp} in muon arms - is 1D trigger really OK?

$D \rightarrow K\pi$ is a problem, but I have not discussed it here because it is a central arm issue. Possibly use single lepton triggers (detecting the recoil c quark).